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Modelling of Neuro Fuzzy Controller for Negative Output KY Boost Converter Voltage Ripple Reduction

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***Abstract*—Negative output KY Boost converter is a recently proposed system by K. I. Hwu et. Al. This converter produces low output voltage ripple than the conventional DC-DC negative voltage boosting converters. In this manuscript a Neuro Fuzzy controller is modeled to control the output voltage ripple and to reduce the peak overshoot and settling time of the converter. The results of proposed Neuro Fuzzy controlled negative output KY boost converter with the digital simulation by Matlab/Simulink® shows reduction in voltage ripple from 60 milli Volts of the existing PI controlled system to 3 milli Volts by the proposed Neuro Fuzzy controlled negative output KY boost converter. Also the peak overshoot of the system and its settling time are reduced to a greater extent with the proposed system.**

***Index Terms*—DC-DC converter, KY boost converter, neuro fuzzy, ripple reduction.**

I. INTRODUCTION

Rapid development of communication systems necessitate reliable negative output DC boosted voltage source. The ripples in output of such sources tend to cause noise in the output of communication system forcing the designer to ensure low ripple content of the source. The output of boost converters such as Luo converters [1]–[3], Cuk converters [4] produce low output ripple. However they require many components when compared to conventional DC-DC boosting converters. In contrast to this, negative output KY boost converter [5] which is recently proposed negative voltage boosting DC-DC converter by K. I. Hwu et. Al., produces very low output voltage ripples of around 60 milli volts with lesser components. Nevertheless the ripple content has to be very lower than 10 mV for the communication systems. As a result of this demand we have designed a Neuro Fuzzy controller to minimize the ripple content of negative output KY boost converter which is presented in this paper.

II. PROPOSED CONTROLLER SYSTEM

Fig. 1 shows the Neuro Fuzzy Controller for voltage regulation of Negative output KY boost converter.

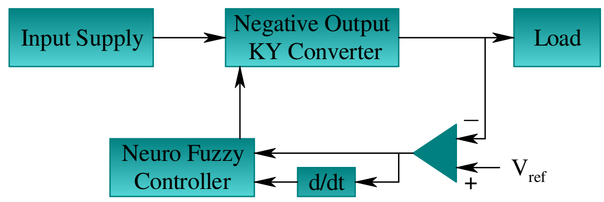

Fig. 1. Neuro Fuzzy controlled Negative output KY Boost Converter block diagram.

The major blocks of the proposed system are voltage source (V_i), Negative output KY boost converter, Load (R), comparator and Neuro Fuzzy controller. The comparator compares the actual output (V_o) with the reference voltage (V_{ref}) to produce error (e) signal and its change with respect to time (ce) are fed as input to the Neuro Fuzzy controller. The output of Neuro Fuzzy is duty cycle (d) fed to PWM generator and the output PWM pulse is fed to the KY converter as switching signal. The subsequent sections describe the operation of negative output KY boost converter, design of Neuro Fuzzy controller, the outputs obtained from digital simulation and the comparison of proposed controller output along with the existing technique output.

III. NEGATIVE OUTPUT KY BOOST CONVERTER

Negative output KY boost converter [5] consists of one MOSFET switch S with body diode D_s; inductor L; energy transferring capacitor C_b; output capacitor C_o; output load resistor R with freewheeling diode D_f and energy transferring diode D_b as shown in Fig. 2.

There are two modes of operation based on switching of the MOSFET switch S namely Mode 1 and Mode 2. In Mode 1 switch S is switched ON whereas in Mode 2 switch S is switched OFF.

Mode 1: In this mode switch S is switched ON there by inductor L is magnetized to a voltage of V_i and simultaneously capacitor C_b is charged as diode D_f conducts, whereas load R is supplied by capacitor voltage C_o. The differential equations given by equation (1) represent the

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mode 1 operation:

$$\begin{cases} L\dfrac{\partial iL}{\partial t} = vi, \\ Co\dfrac{\partial vo}{\partial t} = -\dfrac{vo}{Ro}, \\ ii - iL = Cb\dfrac{\partial vi}{\partial t}. \end{cases} \tag{1}$$

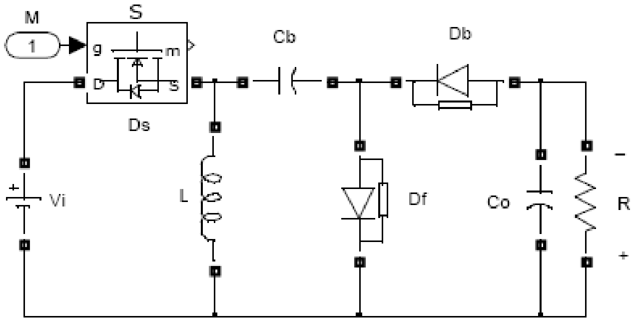

Fig. 2. Negative output KY boost converter.

Mode 2: In this mode switch *S* is switched OFF there by demagnetizing inductor *L* and capacitor C_b discharges, hence D_b conducts forming a power flow across the load *R*, which is represented by the differential equation (2) as follows:

$$\begin{cases} L\dfrac{\partial iL}{\partial t} = vi - vo, \\ iL = -ib. \end{cases} \tag{2}$$

From the above equations (1) and (2) of mode 1 and mode 2, the correlation between DC input voltage (V_i) and DC output voltage (V_o) is characterized by equation (3) as follows, in which *D* is the duty cycle

$$\frac{Vo}{Vi} = \frac{1}{1-D}. \tag{3}$$

Table I gives the specification of negative output KY boost converter which K. I. Hwu et. Al. [5] had proposed with a PI controller for the negative output KY boost converter control. We have taken into consideration of the above said specification to compare the output of the proposed Neuro Fuzzy controller output with the existing one.

TABLE I. NEGATIVE OUTPUT KY BOOST CONVERTER SPECIFICATIONS.

Parameter	Value	Unit
Input Voltage	5	V
Rated Output Voltage	12	V
L	10	μH
C_o	2200	μF
C_b	1000	μF
R	6	Ohm
Switching frequency	195	KHz

IV. NEURO FUZZY CONTROLLER MODELING

Neuro Fuzzy controller [6]–[9] modeled for Negative output KY boost converter is shown on Fig. 3. The output voltage of the negative output KY boost converter is compared with reference voltage by the comparator and the output of converter is error signal which is fed to the Neuro Fuzzy controller along with the change in error signal. The output of controller is duty cycle fed to PWM block and the PWM output is fed as switching signal to the KY converter as shown in Fig. 3.

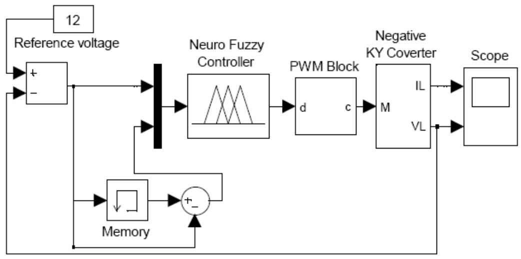

Fig. 3. Adaptive Neuro Fuzzy controller for 2-stage KY converter.

A Neuro Fuzzy controller is realization of Neural Network in a Fuzzy rule base as shown in the following block diagram of Neuro Fuzzy controller [6]-[9] in Fig. 4.

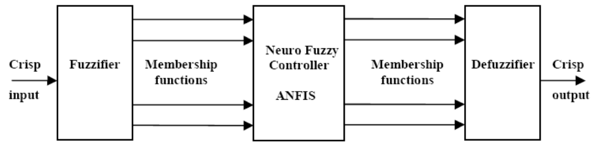

Fig. 4. Adaptive Neuro Fuzzy controller block diagram.

The fuzzifier inputs consists of two inputs error (*e*) and change in error (*ce*) and these inputs are classified into 5 membership functions namely Negative Big (NB), Negative Small (NS), Zero (ZE), Positive Big (PB) and Positive Small (PS). The membership function shapes are chosen as “gauss2mf” membership function. Fig. 5 shows the membership function of input variable error (*e*) and the input is chosen by ANFIS from 0 to 12 in volts. Fig. 6 shows the membership function view of input variable change in error (*ce*) whose input range is from -0.001 to -0.035 in volts.

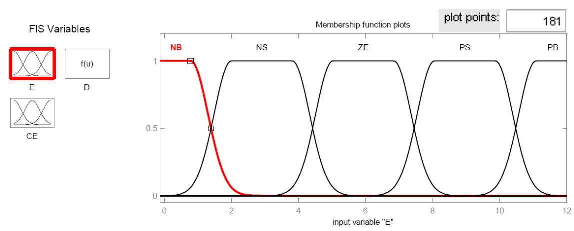

Fig. 5. Membership function of error.

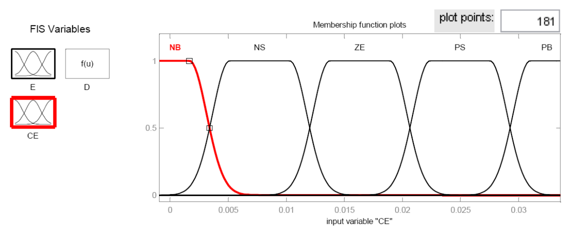

Fig. 6. Membership function of change in error.

The defuzzifier of the Neuro Fuzzy system (ANFIS) is the output function which is the duty cycle (*d*), which is selected as a linear membership function consisting of 25 membership functions corresponding to the input five membership functions of two input variables. The ANFIS rule base in this article is created by grid partitioning method [6] as shown in Fig. 7. The rule base consists of 25 rules, corresponding to the 5 membership functions of the two inputs error (*e*) and change in error (*ce*). The output of the ANFIS is duty cycle (*d*), is a function of summation of the outputs of the 25 rule base as depicted by architecture of ANFIS shown in following Fig. 8.

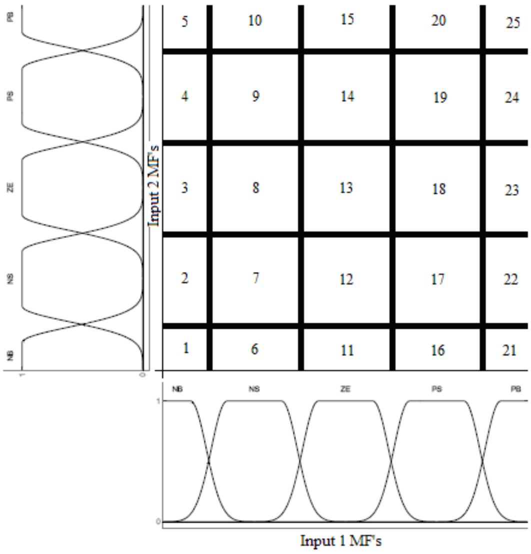

Fig. 7. Grid partitioning technique of ANFIS rule base.

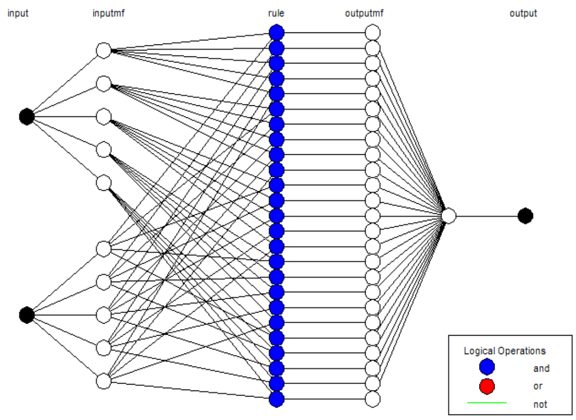

Fig. 8. ANFIS architecture rule base.

Fig. 9. ANFIS training output.

The ANFIS is loaded with the datasets obtained from the Simulink workspace. The datasets consists of the inputs "e", "ce" and output "d". The training method employed here is hybrid which is combination of both least square method and back propagation method. The training is carried out for 50 epochs for a constraint of minimum error. Fig. 9 shows the training output of the ANFIS and the Fig. 10 shows the surface view of ANFIS rule base before training the ANFIS and Fig. 11 shows the surface view of ANFIS rule base after training.

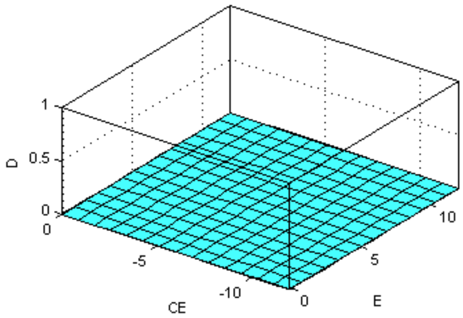

Fig. 10. Surface view of ANFIS rule base before training.

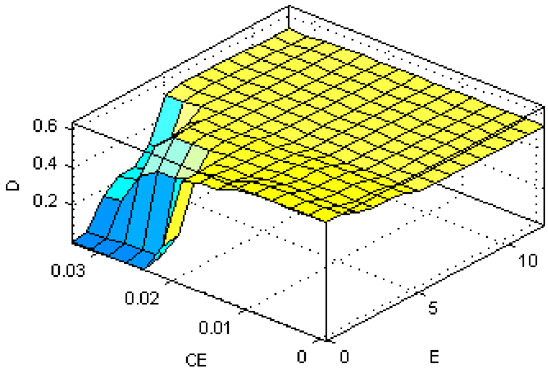

Fig. 11. Surface view of ANFIS rule base after training.

V. RESULTS

The digital output of proposed Neuro Fuzzy controller is shown in Fig. 12 which shows the output voltage and current waveform against corresponding time of the proposed system. Fig. 12 exhibits a settling time of output voltage as 4 milli seconds.

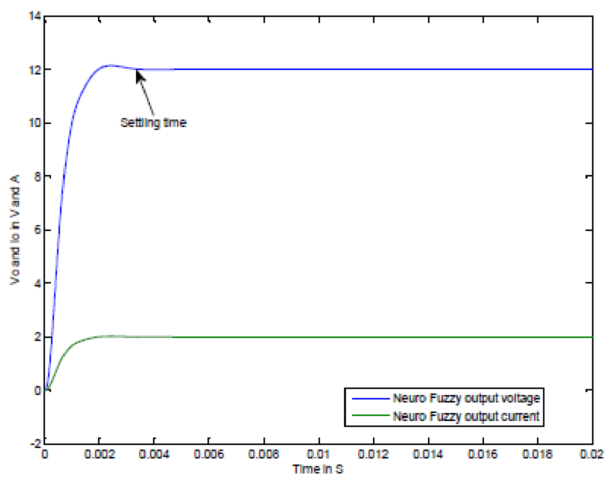

Fig. 12. Waveform of output voltage and current versus time.

Fig. 13 shows the waveform of output voltage ripple and the ripple is found to be 3 mV. Whereas in the existing PI controlled negative output KY boost converter [5], the output voltage ripple was 60 mV.

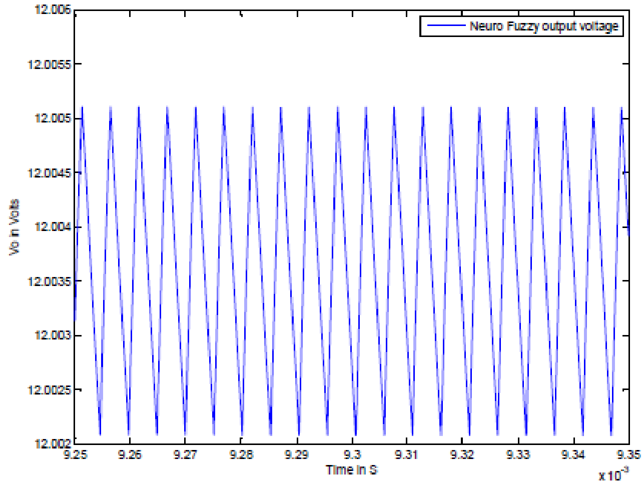

Fig. 13. Waveform of output voltage ripple.

Fig. 14 shows the comparison waveform of output voltage of existing PI controlled converter and proposed Neuro Fuzzy controlled converter, which exhibit a reduction in peak overshoot of the output voltage from 2 volts to few milli Volts.

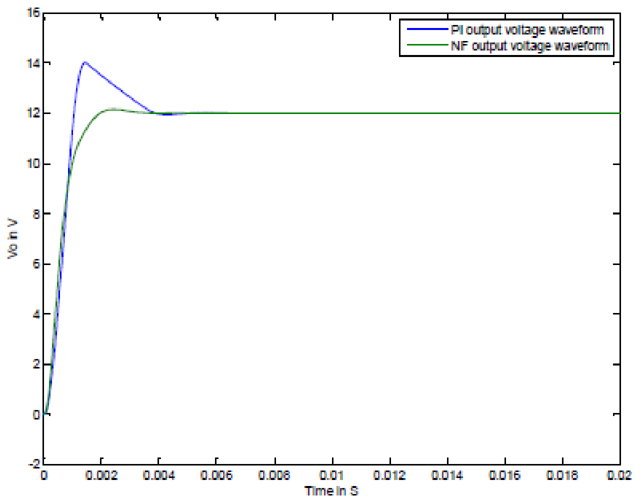

Fig. 14. Comparison of PI and Neuro Fuzzy output waveforms.

The following Table II shows the comparison waveform of output voltage of existing PI controlled converter and proposed Neuro Fuzzy controlled converter, which shows that the output ripple content is reduced from 60mV to 3 mV and the settling time is improved to 4mS with a reduction in peak overshoot to few mV.

TABLE II. COMPARISON OF EXISTING AND PROPOSED CONTROLLER OUTPUT

Parameter	Existing controller	Proposed Neuro Fuzzy controller
Output Voltage ripple	60 mV	3 mV
Settling time	25 mS	4 mS
Peak overshoot	2 V	50 mV

VI. CONCLUSIONS

The proposed Neuro Fuzzy controller for negative output KY boost converter modeled in this article demonstrate reduction in output voltage ripple from 60 mV to 3 mV with decrease in settling time and reduction in peak overshoot of the output when compared with the existing PI controlled system. The performance exhibited by the proposed system is well suited for communication system applications. The performance of this converter can be enhanced by implementing various optimization techniques.

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